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BULLETIN No. 87.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
A. C. TRUE, Director.

IRRIGATION IN NEW JERSEY.

BY

EDWARD B. VOORHEES, M. A.,
Director New Jersey Agricultural Experiment Stations and Professor of Agriculture Rutgers College.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1900.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., July 13, 1900.

Sir: I have the honor to transmit herewith and to recommend for publication as a bulletin of this Office a paper on Irrigation in New Jersey by Prof. Edward B. Voorhees, director of the New Jersey Agricultural Experiment Stations.

This bulletin has been prepared under the supervision of Mr. Elwood Mead, expert in charge of the irrigation investigations of this Office, and reports the results of experiments conducted for the purpose of determining whether irrigation during short periods of drought in regions where the rainfall is usually sufficient for the maximum growth of crops will sufficiently increase the yield to pay for the works necessary to obtain the supply of water.

So far as rainfall conditions are concerned, New Jersey belongs to the so-called humid region, and may be considered typical of the whole eastern half of the United States. Judging from the results reported in this bulletin, there seems to be no doubt that irrigation for fruits and market gardens, even in regions where rainfall is normally abundant, is a profitable undertaking. The work in New Jersey is a part of an investigation of the problems of irrigation now being carried on by the Office of Experiment Stations in different regions of the United States, the results of which have been partially reported in previous bulletins of this series.

Respectfully,

A. C. True,
Director.

Hon. James Wilson,
Secretary of Agriculture.

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IRRIGATION IN NEW JERSEY.

INTRODUCTION.

Little importance has thus far been attached to the matter of irrigation in the Eastern States. This is due in large part to the fact that the rainfall is usually sufficient to meet the needs of vegetation and because serious or long protracted droughts are the exception rather than the rule. Owing, however, to the changes which have taken place in recent years in the character of the farming, attention has been aroused to the importance of controlling the moisture of soils rather than accepting the conditions as they exist, and a deficiency of rainfall for even a short period is now found to be more disastrous than the long periods of drought under old conditions of farm practice, though, even under extensive systems of farming, the losses from drought are often very serious. For example, in the season of 1899 it was so dry in May and early June that the yield of hay, an important crop in the East, was very light in New Jersey. The shortage in this crop amounted to more than one-half, which at a low estimate averaged \$50 per farm, or a loss of more than \$1,500,000 for the State. In the dairy regions the deficiency of rainfall also materially reduced the yield of the pasture and early forage crops, thus affecting the returns from this branch of farming. So seriously does a deficiency of rainfall affect the dairy interests that many progressive farmers now regularly plant a supplementary crop to provide sufficient forage in case of drought. It pays better to have an excess of forage, which may be wasted in part, in a good season, than to have a shortage. The deficiency of rainfall in 1899 also resulted in very serious injury to early crops, particularly asparagus, strawberries, and other berries; early beets and many other important early crops were also affected. It is perhaps not practicable, and it may not be possible, in many parts of the East to provide for the irrigation of the entire farm area. It is not known how far it would be practicable; hence it is eminently desirable that inquiry should be made concerning the question in the East and that experiments be carried out to determine whether a largely increased yield may be expected from irrigation, and thus show whether it is likely to prove a practicable and profitable undertaking.

SHORTAGE OF WATER IN HUMID REGIONS.

The fact that the conditions in the East are such as to make it seem that there is an abundance of water has also tended to obscure the real importance of the question—rains do come, and then the necessity and possible advantages of irrigation are lost sight of or forgotten until another drought occurs.

In New Jersey the need for irrigation is not apparent when the average annual rainfall is considered. This varies from 44.09 inches in the northwest to 49.7 inches on the seacoast, though the annual precipitation occasionally sinks as low as 31.05 inches in some localities, which is as low as the annual rainfall on the border of the subhumid regions of the West, and droughts during the growing months—April to August, inclusive—which result in a very considerable loss, occur more frequently than is popularly supposed. In other words, the average rainfall, while sufficient to meet the needs, if properly distributed, is found to be very unevenly distributed. Besides, much of the rain that falls during the summer months proves of little service, as the dashing showers, so common in summer, do not penetrate the soil as do the early spring and late fall rains, and a large proportion runs from the surface. Thus the statement of monthly rainfall, or even that during the growing season, is not a guide as to its efficiency unless accompanied by statements as to the character of the fall. In a large percentage of years there are one or two months during which the deficiency of rainfall is so serious as to cause a marked if not an entire loss of crop.

As an illustration of this point the following data from the Rutgers College farm records are interesting: In 1897 and 1898, years of abundant rainfall in April and May, the yield of hay averaged 2.65 tons per acre. In 1899 it was but a fraction over 1 ton, owing to the deficiency of rainfall in April and May—at the low price of $10 per ton, a loss for the 25 acres of over $400. The yield of crimson-clover forage for 1897 and 1898 was 8.5 tons per acre; in 1899 the yield was but 5 tons, or in a good year the yield was 70 per cent greater. The deficiency in the rainfall at the critical period was alone responsible for this difference in yield, as the catch was good and the land quite as fertile and as well prepared and fertilized as in the years of abundant rainfall. Oat and pea forage in 1897 and the early seeding of 1898 averaged 6 tons per acre; in 1899 the yield was but 3.3 tons. These figures from the carefully kept records of the farm show that a shortage of water at critical periods of growth does result in seriously reducing the returns that could reasonably be expected under favorable conditions.

The rainfall records in Philadelphia from 1825 to 1895 (70 years), for example, show that in 88 per cent of the years there was a deficiency of over 1 inch for one month, or that in 62 years out of the 70

there was one month in the growing season from April to August in which such a marked deficiency occurred as to cause a serious shortage of crop, and that for the same period there were 39 years in which the deficiency extended throughout two months, while in 21 years it extended throughout three months, or in 30 per cent of the years included in this record there were three months during the growing period in which the average rainfall was deficient 1 inch or more. It is thus observed that a wide series of crops would be likely to suffer in more than one-half of the years for which the record is available, while a still larger number would suffer in nearly one-third of the years, for it must be remembered that even a slight deficiency in one month may result in serious reduction in yield and consequent loss if it occurs at the time when the crop is making its largest development, as, for example, the grasses in May, and other forage crops in June or July or August; or when the crops are ripening, as berries in June or July; or in the case of the growth of vegetables, whose whole period of growth is included in one month.

AMOUNT OF WATER REQUIRED.

In making plans for irrigation, however, it is desirable to have definite data in reference to the water needed as a basis for calculation. As already pointed out, the average rainfall in New Jersey represents conditions very favorable to good crops, provided the distribution is relatively uniform throughout the growing season; hence the amount necessary for irrigation may be safely estimated to be the difference between the average and the minimum rainfall for the various periods. The lowest amount of rainfall from April to August, 1880 to 1895, inclusive, is found to be 9.33 inches, and by seasons the lowest for the spring, 5.23 inches, and for the summer, 4.62 inches.[1]

In the southern part of New Jersey, therefore, an equivalent of 12 inches of rainfall will be required for the whole growing season in certain years, and for certain months an equivalent of 4 inches will be required, in order that the deficiency may be met. The irrigation problem, so far as water requirements are concerned, is therefore a more complicated one in the East than in the arid regions, since in a certain number of years very little may be required, while in certain other years the maximum of 12 inches may be necessary. The capacity of irrigation works must be sufficient to meet the maximum requirements, though maximum demands will not be made, judging from past records, oftener than once in three years.

STORAGE OF WATER.

Investigations of the discharge of streams in southern New Jersey show that, with storage plants, an equivalent of 12 inches of rainfall

[1] U. S. Dept. Agr., Office of Experiment Stations Bul. 36.

can be made available for use during the growing season. The estimated cost of storage would, however, be nearly $30 per acre if the capacity of the plant was such as to meet this maximum demand of 12 inches for the entire area. If, however, provision is made to store one-fourth of the amount, 3 inches for the whole area, or 12 inches for one-fourth of the area, the cost for storage would be reduced to $16 per acre.[1] The probabilities are that the area that it is particularly desirable to irrigate would be included in this proportion. This cost of irrigation works is, however, higher than the average for the United States, where irrigation is extensively practiced.

It is not necessary that irrigation should be held in abeyance until the practicability of storage works is determined, for the conditions in this section of the State are favorable to a low cost of irrigation by means of canals and ditches, and it is estimated that 75,000 acres can be watered without the use of storage reservoirs at a cost of about $8 per acre, not including the annual cost of application. Even if one-fifth of this, 15,000 acres, or even a much smaller area, were brought under irrigation in this way, it would enable the gathering of data which would help to determine whether the more expensive storage plants would be likely to prove a financial success. This irrigable area may also be largely increased without storage, by pumping from wells. The areas thus available for irrigation are now mostly under cultivation, and it is estimated that 175,000 acres could be irrigated in this way. Wells capable of providing 25,000 gallons per day, or sufficient water for an area of 10 acres, are found in many parts of southern New Jersey, yet, aside from this, it has been shown that there is enough water wasted annually to irrigate the entire State during the driest year, and, neglecting what may be watered by wells, fully 325,000 acres may be brought under water.[1]

CULTIVATION.

It is well for those who contemplate irrigation, however, to remember that while water is the essential thing in times of drought, there are other conditions which should be considered quite as carefully as if no water is to be applied. That is, if the full duty of water is to be attained, the land upon which it is to be applied should be carefully prepared and measures taken to conserve not only natural but artificial supplies. The character of the soil and subsoil, the distance of the ground water from the surface, and the slope of the land are all factors to be taken into consideration, and both the method of applying water and the quantity used should be adjusted to best meet these conditions. An open soil with porous subsoil will permit the rapid percolation of the water to lower layers, where the roots are located, while a hard surface soil and compact subsoil present conditions that

[1] U. S. Dept. Agr., Office of Experiment Stations Bul. 36.

encourage a slow penetration of water, with a maximum tendency to run off. In the former case preliminary preparation is not required and the application should be such as to gradually and continuously supply needs, while in the latter case the soil should be cultivated to full depth—subsoiled, if need be—and the surface particles made extremely fine, in order to encourage the percolation and absorption of the water, and after the application of water it should be cultivated frequently, in order to prevent the rapid escape of the water into the atmosphere. These are points well understood by the progressive farmer, but with an abundant supply of water the tendency would be to rely too much upon the artificial source of supply, and thus cause a waste. It is to be remembered, too, that water alone will not produce a crop; the land must be made fertile, and because of the larger crops consequent upon irrigation there will be a greater necessity for supplying fertilizers than if a crop fails through lack of water once in two or three years.

TIME OF APPLYING WATER.

Experience has shown that the best method of irrigation in the arid region is to give the land thorough soakings at considerable intervals of time. In that region the rainfall during the growing season is so small as not to enter into the calculations. In New Jersey, however, sudden showers, which result in a rainfall of from 2 to 3 inches, are not unusual. If these come immediately or soon after the application of 1 inch or more of water by irrigation, and the storm is followed, as frequently happens, by damp, muggy weather, the effect of the irrigation may be to decrease the crop rather than increase it, as excessive amounts of moisture under the conditions mentioned are conducive to the rapid spread of blights, diseases, rots, etc., which are likely to reduce the yield, and in many cases prove quite as disastrous as a deficiency of water. This is particularly true in the case of melons, potatoes, berries, etc.; it would not, of course, be the case with the cereals, the grasses, or the summer forage crops. In irrigating in this region it has been found to be a more prudent plan to use the water more frequently and in less amounts than is usual in the arid districts. This, while more expensive of time, obviates the danger here pointed out. It has been the practice here to begin the irrigation when the surface soil became dry and before the plants show any sign of suffering, and then to apply such an amount as will thoroughly moisten the soil and keep the crops growing. The dryness of the soil when necessary to begin, and its moisture when the irrigation should be stopped, are matters that can be learned from experience. The records of applications and the results obtained, on subsequent pages, show what the practice at the New Jersey Station is in the matter of application and the gains from the added water. In brief, the object was to keep the soil moist, which term will be fully understood by all

practical men. To prevent the escape of the water the furrows were turned back and the land cultivated after the water had soaked into the soil.

In the experiments in irrigating berries no specific studies have been made of methods of irrigation; in all cases it has been by what is known as the "furrow system," which has given excellent satisfaction and is described later. It is believed to be the more practicable plan for crops of this sort, and for considerable areas.[1] A broad, shallow furrow was run along the row, and the water turned in in such quantity as to cause it to flow slowly, until the soil between the furrows which contain the row was thoroughly wet. When the water has thoroughly soaked into the soil, the furrows are turned back and the whole cultivated.

EXPERIMENTS IN IRRIGATING SMALL FRUITS, 1898 AND 1899.

The plan and scope of the work undertaken are fully explained in an earlier bulletin of this office,[2] although a brief description is included here. The experiment ground contains 7 acres, separated by lanes 9 feet wide into three divisions, the higher ground in the middle division. The topography of the area shows a fall of 9.25 feet from the highest to the lowest points, and that upon a large portion of the area there is a reasonable uniformity in the slope of the land, thus permitting a ready and sufficiently rapid flow of water. The water is supplied by a 3-inch main, which runs through the middle division; tees are placed every 75 feet, from which laterals, 1 inch inside diameter, are carried both north and south, ending in hydrants raised 3 feet from the ground, and provided with faucets to which hose may be attached for distributing the water. The fall from the reservoir is about 9 feet, thus affording a reasonably rapid flow from the laterals, and the supply is ample for the maximum demands for irrigation purposes.

The division lying on the south contains about 2 acres, and is divided into four plats. The plats vary in size according to the number of varieties of crops included, as well as the distance between the rows, though the irrigated and unirrigated plats for each kind and variety are of the same size, and in all cases, with the possible exception of some of the larger fruits, the plats are large enough to permit of a comparison of the effects of irrigation. In the tables the yields have been calculated to the acre, as a more intelligible basis for comparison. The multiplied errors, if any, are quite as liable to occur in the unirrigated as in the irrigated plats; besides, the percentage increases are given, which are not affected by the multiplication, and are applicable for other conditions.

[1] King, Irrigation and Drainage, p. 383.

[2] U. S. Dept. Agr., Office of Experiment Stations Bul. 36.

The results published here were obtained from plants set in the spring of 1896, and include only blackberries, raspberries, gooseberries, and currants, as indicated, as the crops from the asparagus and from the other fruits have not yet been large enough to permit of a fair comparison. All the crops have been irrigated, the necessity for which is shown in the accompanying meteorological table:

Yearly precipitation on the experiment grounds for the years ended October 31, 1896, 1897, 1898, and 1899.

Year.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Total.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
1896....	3.41	2.68	1.68	5.85	5.92	1.41	3.70	4.93	4.37	2.42	4.81	1.62	54.79
1897....	2.95	1.59	2.39	2.77	2.47	3.47	6.45	2.50	12.84	3.81	2.10	1.59	42.80
1898....	4.52	5.09	3.92	3.49	3.09	4.17	7.86	1.13	3.91	6.44	1.46	5.80	44.93
1899....	7.14	3.16	4.88	5.37	6.63	1.50	2.04	3.54	6.32	3.45	7.80	2.96	50.88

It will be observed that in each year there was one or more months in the growing season, April to August, in which there was a decided deficiency in rainfall—April and August in 1896, June in 1897, June in 1898, and April and May in 1899. The drought was very severe in 1898, and came at a time when blackberries especially were in greatest need of water.

The table given below shows the times of irrigation and the amounts of water applied during the four years for the different crops, and also a comparison of water applied and normal rainfall:

Date of application of water and amount used per plat.

BLACKBERRIES.

Year.	Date of application.	Amount applied.	Equal to inches of rainfall.	Rainfall.	Rainfall plus irrigation.	Normal rainfall.
		Gallons.		*Inches.*	*Inches.*	*Inches.*
1896	May 16	825	0.79			
	June 8	1,096	1.06			
	Total	1,921	1.85	5.11	6.96	7.54
1897	June 21	500	.47			
	June 29	480	.46			
	July 8	350	.33			
	Total	1,330	1.26	2.50	3.76	3.05
1898	June 25	800	.62			
	June 30	450	.45			
	July 5	1,035	1.00			
	July 9	450	.45			
	July 16	200	.21			
	July 26	225	.23			
	Total	3,160	2.96	5.04	8.00	7.33
1899	May 26	500	.47			
	June 3	1,023	.98			
	Total	1,523	1.45	5.58	7.03	7.23

Date of application of water and amount used per plat—Continued.

RASPBERRIES.

Year.	Date of application.	Amount applied.	Equal to inches of rainfall.	Rainfall.	Rainfall plus irrigation.	Normal rainfall.
		Gallons.		*Inches.*	*Inches.*	*Inches.*
1896	May 15	840	1.11			
	June 6	1,200	1.58			
	Total	2,040	2.69	5.11	7.80	7.54
1897	June 19	660	.87			
	June 28	522	.69			
	July 19	450	.60			
	Total	1,632	2.16	2.50	4.66	3.05
1898	June 24	810	1.09			
	June 29	450	.60			
	July 6	540	.72			
	July 8	540	.72			
	Total	2,340	3.13	5.04	8.17	7.33
1899	May 29	715	.94			
	July 8	715	.94			
	Total	1,430	1.88	5.58	7.46	7.23

GOOSEBERRIES.

Year.	Date of application.	Amount applied.	Equal to inches of rainfall.	Rainfall.	Rainfall plus irrigation.	Normal rainfall.
1896	May 13	210	.52			
	June 8	245	.60			
	Total	455	1.12	5.11	6.23	7.54
1897	June 18	180	.47			
	July 9	300	.78			
	Total	480	1.25	2.50	3.75	3.05
1898	June 23	450	1.17			
	July 2	330	.88			
	July 11	270	.71			
	Total	1,050	2.76	5.04	7.80	7.33
1899	June 1	310	.79	5.58	6.37	7.23

CURRANTS.

Year.	Date of application.	Amount applied.	Equal to inches of rainfall.	Rainfall.	Rainfall plus irrigation.	Normal rainfall.
1896	May 13	300	.78			
	June 8	210	.52			
	Total	510	1.30	5.11	6.41	7.54
1897	June 18	210	.52			
	July 9	300	.78			
	Total	510	1.30	2.50	3.80	3.05
1898	June 24	300	.78			
	July 2	270	.71			
	July 11	270	.71			
	Total	840	2.20	5.04	7.24	7.33
1899	June 1	310	.79	5.58	6.37	7.23

The four plats in the case of any one variety differ only in the kinds of fertilizer applied. Plat 1 received yard manure at the rate of 20 tons per acre; plat 2, a complete fertilizer containing 4.5 per cent nitrogen, 7.7 per cent phosphoric acid, and 13.3 per cent potash; plat 3 received 300 pounds per acre of an even mixture of ground bone

and muriate of potash; plat 4 received 300 pounds per acre of an even mixture of ground bone and potash, and 200 pounds of nitrate of soda per acre. Plats 1 and 2, therefore, may be regarded as having been supplied with an abundance of all of the constituents and in such forms as to supply the entire needs of the plants. The larger yield on the manured plat for 1898 is due to the fact that nearly every plant grew, while on the other plats many died during the summer of 1896, hence the greater age and vigor of the plants encouraged the larger yield that year. The comparison as to irrigation is, however, not affected. With the exception of 1897 the total rainfall was fully up to the normal, yet in the region of the State in which the station is located the normal rainfall is usually sufficient to perfectly mature crops. While during a drought the atmospheric and temperature conditions are usually such as to cause a more rapid drying than would be the case with frequent light rainfalls and a larger proportion of cloudy days, the amounts applied were adjusted as nearly as it was possible to do so, in order to provide an equivalent to a normal rainfall, taking into consideration the relatively more rapid evaporation of water from the surface due to a greater proportion of sunshine. The results obtained also clearly demonstrate that it is not possible to closely approximate the influence upon growth and development of the kind of crops under experiment of an excessive rainfall during a month previous to the one of great deficiency, though care was taken by means of frequent cultivation to conserve the excess of that month. In 1898, for example, the excess over the normal for May was more than sufficient to meet the deficiency in both June and July, yet notwithstanding this excess the deficiency in those months caused a very serious injury to the crops, as shown by the yield on the unirrigated plats. The influence of the excess in May was not marked and an application of water during June and July, equivalent to 3 inches of rainfall, caused a decided increase in crop.

The most serious deficiency in rainfall for these crops occurs in one month, and the first application was made usually before the plants really suffered, but when it was known that a deficiency existed without special testing of the soil. Owing to the character of the plants no water was applied when a marked deviation from the normal rainfall occurred after the crops were harvested, as was the case in the month of September, 1897, and 1898. Naturally, in 1896, the season in which the plants were set, the effect of the added water could not be measured, neither could it be measured with any degree of accuracy in 1897, as the crops were still very small. The effect, if any, of the added water in those years can be shown only by a comparison of the yields in 1898 and 1899. It will be observed from the table that in case of nearly all the crops the amount of water applied was practically such as to meet the deficiency in rainfall, and naturally the

larger amount was applied just previous to or during the time when the fruits were ripening.

At no time during the season in any year did the growth on the irrigated plats show any evidence of lack of water; the growth and development of both plant and fruit was normal, while upon the unirrigated plats the leaves and fruit, and in many instances the plants were killed, though these plats were frequently cultivated in order to retain the maximum soil moisture for the use of the plants. It may be said here, too, that the full value of the added water is not really expressed by the number of quarts of increased product, as the berries upon the irrigated areas were superior in quality, which is not shown by a comparison of the yields. That is, the berries on the irrigated plats were large, sweet, and succulent, while those on the unirrigated were small, sour, and hard. The only evidence of ripeness in the case of the blackberries was the fact that they were black.

BLACKBERRIES.

The following table of yields of blackberries in 1898 and 1899 show that different varieties of this fruit differ widely in reference to their drought-resisting power, and consequently in the benefits that may be derived from irrigation. Since only plats 1 and 2 represent what may be regarded as good conditions of manuring, the yields of these plats only are considered:

Yields of blackberries per acre on irrigated and unirrigated plats, 1898 and 1899.

Variety.	1898.		1899.	
	Plat 1.	Plat 2.	Plat 1.	Plat 2.
Early Harvest:	*Quarts.*	*Quarts.*	*Quarts.*	*Quarts.*
Irrigated	5,070	2,795	2,018	3,230
Unirrigated	4,069	2,499	1,105	1,397
Gain from irrigation	1,001	296	913	1,833
Wilson Jr.:				
Irrigated	2,665	3,344	2,596	2,827
Unirrigated	409	1,725	721	1,092
Gain from irrigation	2,256	1,619	1,875	1,735
Erie:				
Irrigated	2,847	1,196	1,199	3,282
Unirrigated	2,808	3,360	390	747
Gain from irrigation	39	−2,164	809	2,535
Agawam:				
Irrigated	2,385	3,149	3,828	4,758
Unirrigated	1,105	2,830	1,722	3,139
Gain from irrigation	1,280	319	2,106	1,618
Taylor:				
Irrigated	4,182	3,068	1,885	2,561
Unirrigated	1,212	533	793	1,352
Gain from irrigation	2,970	2,535	1,092	1,209
Eldorado:				
Irrigated	7,985	2,535	3,870	6,571
Unirrigated	4,026	204	1,462	1,862
Gain from irrigation	3,959	2,331	2,408	4,709

A study of the yields in 1898 shows a wide range on both the unirrigated and irrigated land for the different varieties. On the unirrigated the lowest yield is 409 quarts for Wilson Jr., and the highest 4,026 quarts for Eldorado, while on the irrigated plats the lowest yield is 2,385 quarts for Agawam, and the highest 7,985 quarts for the Eldorado. On plat 2 the lowest yield, unirrigated, is 204 quarts for Eldorado, and the highest 3,360 quarts for the Erie, while on the irrigated the lowest yield is 1,196 quarts for the Erie and the highest 3,344 quarts for Wilson Jr. A very wide variation in the yield of the unirrigated, as well as the irrigated, is due to the variety of the berry, and is in part caused by the difference in time of ripening. The date of the first picking of the different varieties is as follows:

Variety.	1898.	1899.
Early Harvest	July 4	June 30.
Wilson Jr	July 8	July 8.
Eldorado	July 14	Do.
Erie	....do...	July 12.
Agawam	July 16	July 10.
Taylor	July 19	July 15.

Out of the 24 possible comparisons, however, 23 show an effect from irrigation, and in 14 cases out of the 24 the irrigation has resulted in an increase in yield of over 100 per cent. In 1899 the lowest yield on the unirrigated plat No. 1 was 390 quarts for the Erie, and the highest 1,722 quarts for the Agawam, while the lowest yield from the irrigated is 2,561 quarts for the Taylor, and the highest 6,571 quarts for the Eldorado. The difference observed in the varieties for the two years is undoubtedly due in part to the different period in which the drought existed. Taking the average of the yield of all the plats, the unirrigated was 1,690 quarts and the irrigated was 3,327 quarts per acre, or a gain from irrigation for all varieties for the two years of 1,637 quarts per acre, or 97 per cent, a gain in quarts larger than that obtained as the average yield of the State. It thus seems to be not only a question of berries, but a question of the variety as well. This is not a place to discuss the relative advantages of different varieties of blackberries, still the striking differences in yields, both under natural and artificial conditions in reference to water supply, show the importance of a study of this point.

A study of the preceding table shows very clearly the effectiveness of irrigation for this fruit. A decided benefit is shown in 75 per cent of the cases in which a comparison of varieties and methods of treatment is possible; in other words, it is demonstrated that it is not a question of particularly good circumstances, as the conditions as to variety and method of fertilization are widely variable. To bring out the points more clearly, and to show what may be expected under average conditions of treatment, a table has been prepared which shows the

average yields of all of the plats, irrigated and unirrigated, for each variety for 1898 and 1899, as well as the average yields for the two successive years:

Average yields of blackberries per acre on all the plats, 1898 and 1899.

Variety.	Irrigated.	Unirrigated.	Gain from irrigation.	
	Quarts.	*Quarts.*	*Quarts*	*Per cent.*
Early Harvest:				
1898	2,805	2,404	401	16.6
1899	2,607	1,443	1,164	80.7
1898–99	2,706	1,923	783	40.5
Wilson Jr.:				
1898	2,182	1,624	558	34.0
1899	2,164	1,275	889	70.0
1898–99	2,173	1,449	724	50.0
Erie:				
1898	1,437	3,418	....	....
1899	2,693	1,542	1,151	74.6
1898–99	2,065	2,480	....	....
Agawam:				
1898	4,218	2,461	1,757	71.4
1899	4,935	3,293	1,642	50.0
1898–99	4,576	2,877	1,699	59.0
Taylor:				
1898	2,497	661	1,836	277.0
1899	2,148	1,995	153	8.0
1898–99	2,323	1,328	995	74.8
Eldorado:				
1898	3,026	1,201	1,825	152.0
1899	4,911	1,848	3,063	165.0
1898–99	3,969	1,525	2,444	160.0

It will be observed that there is a gain from irrigation in the case of every variety except the Erie, and that in the majority of cases irrigation has resulted in largely increased yields. Excluding the Erie, the average gain for the two years ranges from 724 to 2,444 quarts per acre. The larger figure represents a fairly high yield in itself, and shows that the best returns are obtained with the best variety. The value of irrigation is, however, not measured by yield alone, for it is a well-known fact that, notwithstanding the present facilities for the distribution of fruits, a serious shortage in the yield of such a perishable product as berries in any one State, or in the section of a State in which the crop is an important one, has its influence upon the price received per quart, particularly in the smaller towns, so that the gain due to irrigation is influenced by the enhanced price received; that is, the average price in a season of abundant rainfall is not a guide as to the prices that may prevail in a season of shortage. This consideration is a most important one, so long as irrigation is confined to limited areas. In 1898 the wholesale price of blackberries was 10 cents per quart; that is, buyers were anxious to get them at that price, owing to the shortage of the crop in the State, due to the drought

preceding their ripening, which practically ruined the crop in many sections of the East. In 1899 the shortage was not so serious; nevertheless they were readily sold at 8 cents per quart, making an average for the two years of 9 cents per quart, or a wholesale price 2 cents per quart above what is regarded as fairly remunerative.

On the basis of this average price the increased value per acre of the berries on the irrigated plats ranged from $65.16 for Wilson Jr., to $219.96 for Eldorado; or, averaging all of the varieties for both years, we have a gain from irrigation of 53.8 per cent, or 1,038 quarts per acre, worth $93.42.

The statistics gathered by the New Jersey Station in 1895 concerning the growth of blackberries showed that upon the clay loam soils the average yield per acre for 1893 and 1894 was 1,300 quarts, and that upon the sandy soils the average yield for the same period was 834 quarts per acre. The soil of the experiment ground is a clay loam and may be safely regarded as representative of the average for the State. Applying the average percentage gain obtained on all the varieties by irrigation for the two years 1898 and 1899 to the average yield of the State, we have an increase of 699 quarts per acre, worth $62.91. In the case of the sandy soils the results from irrigation would doubtless be more striking than in the case of the clay loams, since while the crop might not suffer any sooner, the greater capacity of such soils to absorb heat would cause a more rapid drying of the berries; still, with the same increase from irrigation the gain would be 449 quarts per acre, worth $40.41. The yields here quoted are the average, and do not represent even good conditions of soil and management, as many growers believe that the berries are better adapted for the poorer light soils than for the heavier and more fertile ones. The application of the percentage increase from irrigation does not, therefore, fully show the possible advantages to be derived. The maximum yield reported for New Jersey was 8,000 quarts, which doubtless represents the best conditions as to soil, season, and variety, since it corresponds to that obtained on the irrigated plat in 1898, viz, 7,985 quarts. In New York State the average yield reported is 3,158 quarts, with a maximum of 10,000 quarts.

Assuming that the average yield in New York could be increased 53.8 per cent by irrigation, the gain per acre would be 1,700 quarts, worth $153. That this gain is quite possible is also clearly shown by the report, which indicates that under best conditions the yield may reach 10,000 quarts. Assuming that the necessity for irrigation is apparent only once in two years, and the average yield under average conditions of treatment without irrigation is 1,500 quarts per acre for the two States, the gain would be 403½ quarts per year, which at 9 cents per quart is $36.32, or equivalent to an interest of 6 per cent on an outlay of $600 per acre, which is more per year than the cost of

irrigation work planned on a large scale, or more than the total cost of small plants capable of irrigating 6 to 8 acres. This would seem to be a fair statement, and applies to average rather than good conditions of manuring and cultivation. This return would be sufficient the first year to pay much more than the full cost, and the surplus may be applied to the extra cost of growing the crop under irrigation. It is recognized that the growing of blackberries is not a large industry, still the statistical reports for New Jersey in 1895 showed an area of 2,850 acres, distributed in areas of from 1 to 4 acres, and chiefly located in sections of the State where irrigation could be practiced. Even if only one-quarter of the total area is capable of irrigation, and assuming the low average yields now obtained, the gain from irrigation on this basis would mean an addition of over $25,000 to the net returns of the grower.

RASPBERRIES.

The following table shows the yields of raspberries for the years 1898 and 1899 on irrigated and unirrigated plats:

Total yields of raspberries per acre on irrigated and unirrigated plats, 1898 and 1899.

Variety.	1898.		1899.	
	Plat 1.	Plat 2.	Plat 1.	Plat 2.
Cuthbert:	*Quarts.*	*Quarts.*	*Quarts.*	*Quarts.*
Irrigated	4,072	1,485	4,702	4,573
Unirrigated	2,655	1,062	3,979	4,227
Gain from irrigation	1,417	423	723	345
Marlboro:				
Irrigated	2,556	562	2,138	2,217
Unirrigated	1,251	369	1,732	1,732
Gain from irrigation	1,305	193	406	485
Turner:				
Irrigated	1,593	733	2,009	1,762
Unirrigated	778	886	2,653	2,138
Gain from irrigation	815	—153	—644	—376

Comparing plats 1 and 2, as in the case of the blackberries, it is observed that in 1898 in five cases out of the six there is a gain in yield from irrigation, and that the differences due to the variety are quite as marked as in the case of the blackberries. The lowest yield on plat 1, unirrigated, is for Turner, 778 quarts, and the highest, 2,655 quarts, for Cuthbert, while the lowest from the irrigated on the same plat is 1,593 quarts, for Turner, and the highest 4,072 quarts, for Cuthbert. The lowest yield on plat 2, unirrigated, is 369 quarts, for Marlboro, and the highest is 1,062 quarts, for Cuthbert, while the lowest from the irrigated plat is 562 quarts, for Marlboro, and the highest is 1,485 quarts, for Cuthbert. In 1899 irrigation was effective in four out of the six cases, though in no case was the advantage from irrigation as great as in 1898, nor were the variations in yield as marked as in

that year. The average gain from irrigation for the two years was 618 quarts per acre, or 20 per cent.

The following table shows the average yields for all the plats, and the actual and percentage gain from irrigation:

Average yields of raspberries per acre on all the plats for 1898 and 1899.

Variety.	Irrigated.	Unirrigated.	Gain from irrigation.	
	Quarts.	*Quarts.*	*Quarts.*	*Per cent.*
Cuthbert:				
1898	2,076	1,472	604	41.0
1899	4,593	4,261	332	7.7
1898-99	3,335	2,866	468	16.3
Marlboro:				
1898	1,065	624	441	70.7
1899	2,311	1,509	802	53.1
1898-99	1,688	1,067	621	58.2
Turner:				
1898	837	754	83	10.9
1899	1,457	1,744	−287	....
1898-99	1,147	1,249	−102	....

With the exception of one variety one year (Turner in 1899), there is an increased average yield from irrigation of all the varieties for the two years, ranging from 468 to 621 quarts, which, at 10 cents per quart, shows a gain of from $46.80 to $62.10 per acre. Including the Turner, the average gain for all is reduced to 19 per cent, making 329 quarts, worth $32.90 per acre.

The statistics as to yields show that the average for New Jersey is 1,928 quarts, and for New York 2,201 quarts per acre, with a maximum of 6,000 in the former and 8,000 quarts in the latter. It is to be fairly assumed that the lower average yield is a result in part of the lack of sufficient moisture, inasmuch as the average for these States is slightly higher than the average of the unirrigated plats for 1898 and 1899. Hence, the average percentage increase as shown by the experiments may be safely applied to the average yields of these States, as showing the possible gain from irrigation in years of serious shortage of water. In the case of New Jersey the increased yield represents a value of $36.63 per acre, and in New York, $41.82 per acre. Assuming, as in the case of the blackberries, that the need for irrigation is not apparent annually, but only once in two years, we have an average per year of $18.31 for New Jersey, and $20.91 for New York, considerably lower than in the case of blackberries, yet a sum in excess of that needed to provide for irrigation by permanent storage works. As a business proposition, even the irrigation of raspberries alone is worthy of consideration. The area of red raspberries in New Jersey is 1,052 acres, and in New York the area is considerably larger, owing to the very considerable drying industry there.

It was not possible to include a study of the effect of irrigation on blackcap berries, as the conditions at the experiment grounds were not favorable for this fruit. The area of blackcaps in the State, however, is quite as large as that for the red, and in New York it is considerably larger than for the red. Neither is there any good reason to doubt but that irrigation would have been quite as effective.

CURRANTS.

The yields of currants on irrigated and unirrigated plats for 1898 and 1899 were as follows:

Total yields of currants per acre on irrigated and unirrigated plats, 1898 and 1899.

Variety.	1898.		1899.	
	Plat 1.	Plat 2.	Plat 1.	Plat 2.
Fay Prolific:	*Quarts.*	*Quarts.*	*Quarts.*	*Quarts.*
Irrigated	66	24	1,464	624
Unirrigated	36	84	396	2,340
Gain from irrigation	30	−60	1,068	−1,716
Red Dutch:				
Irrigated	1,194	960	3,264	4,644
Unirrigated	768	192	3,252	1,692
Gain from irrigation	426	768	12	2,952
Victoria:				
Irrigated	1,560	756	4,176	3,072
Unirrigated	1,248	300	3,228	2,472
Gain from irrigation	312	456	948	600
White Grape:				
Irrigated	606	420	1,044	1,560
Unirrigated	492	72	1,032	696
Gain from irrigation	114	348	12	864

Marked differences are also shown in reference to the yields of the different varieties, though in 14 out of the 16 a very decided gain is observed from irrigation. The yield in the case of Fay Prolific was very low in 1898, so that a comparison on the percentage basis would mean but very little; still, for the two years the gain from irrigation is 496 quarts, or a gain of over 43 per cent.

The results of the irrigation on currants are less satisfactory in one sense than upon blackberries and raspberries, owing to the fact that the plants have not yet reached maturity, and therefore the yields are relatively low; still, the percentage of increase in yield due to irrigation is applicable to the averages obtained in the State.

Average yields of currants per acre on all the plats for 1898 and 1899.

Variety.	Irrigated.	Unirrigated.	Gain from irrigation.	
	Quarts.	*Quarts.*	*Quarts.*	*Per cent.*
Fay Prolific:				
1898	42	68	−26	....
1899	1,208	1,328	−120	....
1898–99	625	698	−73	....
Red Dutch:				
1898	966	630	336	53.2
1899	3,760	2,856	904	31.7
1898–99	2,363	1,743	620	35.6
Victoria:				
1898	1,014	696	318	45.7
1899	3,692	2,856	836	29.3
1898–99	2,353	1,776	577	32.5
White Grape:				
1898	444	232	210	90.6
1899	1,212	1,184	28	2.4
1898–99	828	708	119	16.1

As in the case of the berries there is a material difference as to the drought-resisting qualities of the different varieties, Fay Prolific showing the lowest yield, and no effect from irrigation. Red Dutch, which showed a considerably larger yield, was benefited to a greater extent. The gain from irrigation for the two years is 311 quarts per acre, or 31.7 per cent. The average yields of currants for this State are reported as 2,692 quarts, with a maximum of 7,500 quarts, thus indicating, as in the case of the blackberries and raspberries, that the low average is, among other causes, due to a lack of water at the right time.

Applying this percentage we find that the increased yield expected would reach 852 quarts, or, assuming that only one year in two is being benefited, an average per year of 426 quarts, which, at 10 cents per quart, the prevailing price, would be $42.60 per acre. Thus irrigation really benefits in a greater degree the currants than the red raspberries. This was very positively shown in the experiment plats in 1899, where the quality was seriously reduced, owing to the drought. The ground on the unirrigated plat became hot, which, together with the sunshine, caused many berries to become sun scalded. These, of course, could not be separated in the handling, and reduced the market value of the fruit.

GOOSEBERRIES.

As already stated, the results from gooseberries are thus far unsatisfactory, owing largely to the fact that the bushes have not yet matured far enough to bring about a uniformity of yield, though it was observed, as in the case of currants, that the unirrigated plats were very largely

injured by sun scald. The yields for the two years on plats No. 1 and No. 2, and the averages for all plats, are given in the following tables:

Total yields of gooseberries per acre on irrigated and unirrigated plats, 1898 and 1899.

Variety.	1898.		1899.	
	Plat 1.	Plat 2.	Plat 1.	Plat 2.
Downing:	*Quarts.*	*Quarts.*	*Quarts.*	*Quarts.*
Irrigated	2,988	2,292	6,756	6,216
Unirrigated	1,776	1,824	8,268	4,116
Gain from irrigation	1,212	468	—1,512	2,100
Columbus:				
Irrigated	738	84	2,592	1,272
Unirrigated	240	96	3,396	1,656
Gain from irrigation	498	— 12	— 804	—384
Houghton:				
Irrigated	7,588	3,708	9,024	8,748
Unirrigated	6,138	4,344	9,732	5,736
Gain from irrigation	1,450	—636	— 708	3,012
Triumph:				
Irrigated	252	72	1,548	552
Unirrigated	210	192	2,952	1,896
Gain from irrigation	42	—120	—1,404	—1,344

Average yields of gooseberries per acre on all the plats for 1898 and 1899.

Variety.	Irrigated.	Unirrigated.	Gain from irrigation.	
Downing:	*Quarts.*	*Quarts.*	*Quarts.*	*Per cent.*
1898	2,192	1,640	552	33.6
1899	6,140	6,668	— 528	....
1898–99	4,166	4,154	12	.29
Columbus:				
1898	522	250	272	108.8
1899	2,376	2,592	— 216	....
1898–99	1,449	1,421	28	1.97
Houghton:				
1898	5,325	5,302	23	.43
1899	8,768	7,784	984	12.6
1898–99	7,046	6,543	503	7.7
Triumph:				
1898	198	230	— 32	....
1899	1,176	2,552	—1,376	....
1898–99	687	1,391	— 704	....

IRRIGATION OF VARIOUS CROPS BY GEORGE A. MITCHELL, VINELAND, N. J.

The crops noted below were grown with and without irrigation, and special care was taken to treat the irrigated and nonirrigated plats exactly alike. The soil used was a light sand, and though naturally well adapted to the growth of vegetable crops, was deficient in fertilizing elements and was in poor physical condition. It was, however, uniform in character and well suited to the purpose of testing the advantage of an abundant water supply, since, if water would here

result in securing a paying crop, the increase would be likely to be proportionately greater on soils of good character.

One acre of cantaloups, one-half acre of early cabbage, one-quarter acre of onions, about one-eighth acre each of sowed corn, sweet corn, sweet potatoes, Lima beans, and white potatoes, followed by Hubbard squash, and one-sixteenth acre each of watermelons, cucumbers, tomatoes, and carrots were raised.

The acre of cantaloups and half-acre of cabbage were a combined experiment with irrigation and nitrate of soda. Each was divided into eight plats, treated as follows:

Irrigated.

Plat 1.—Stable manure only.

Plat 2.—Stable manure, plus 150 pounds nitrate of soda per acre.

Unirrigated.

Plat 3.—Stable manure only.

Plat 4.—Stable manure, plus 150 pounds of nitrate of soda per acre.

Irrigated.

Plat 5.—Minerals,[1] plus 150 pounds nitrate of soda per acre.

Plat 6.—Minerals, plus 250 pounds nitrate of soda per acre.

Unirrigated.

Plat 7.—Minerals, plus 150 pounds nitrate of soda per acre.

Plat 8.—Minerals, plus 250 pounds nitrate of soda per acre.

CANTALOUPS.

The nitrate of soda was applied in three equal applications: The first in a broad circle about the hill, May 6; the second in the same way, June 9; and the last was applied broadcast, June 22.

The experiment with cantaloups, while showing the superiority of irrigation on plats treated with yard manure over those treated with minerals and nitrate, was a practical failure, owing to the blight of the vines early in the season of picking.

EARLY JERSEY WAKEFIELD CABBAGE.

A red clover sod was plowed under in 1898 on the half acre used for cabbage. The same number of cabbage plants were set out on each plat at each setting—March 27, April 6, 10, and 19. Resetting was as follows:

	Apr. 27.	May 9.
Plat 1	27	13
Plat 2	28	15
Plat 3	34	14
Plat 4	44	19
Plat 5	48	19
Plat 6	46	31
Plat 7	27	20
Plat 8	33	23

[1] By minerals is meant not less than 60 pounds of available phosphoric acid and 100 pounds of actual potash per acre.

All plats were cultivated seven times and hoed once. They were irrigated three times.

Irrigation was not needed so often on plats receiving stable manure. The nitrate of soda was applied broadcast in three equal applications—April 12, May 6, and June 3.

Before irrigation the plats fertilized with stable manure were ahead of those supplied with chemical fertilizer. On May 17 they had been badly eaten with worms. On June 8 the unirrigated cabbage wilted in the middle of the day, and some of the leaves were turning yellow.

The yields were as follows:

Yields of cabbage.

	Before July 10.	Total.
	Pounds.	*Pounds.*
Plat 1	214	[1] 669
Plat 2	271	[1] 639
Plat 3	139	564
Plat 4	173	632
Plat 5	184	[1] 624
Plat 6	200	[1] 644
Plat 7	125	528
Plat 8	127	664

[1] Irrigated.

A study of the yields shows that nitrate of soda affected favorably the earliness of the cabbage, and had a greater effect when used in connection with irrigation than without. Nitrate of soda with barnyard manure, in connection with irrigation, gave the best results. The total yields do not show decisive results of treatment. The rains that fell as the cabbage was maturing had a very beneficial effect.

An examination of the table shows that in every case irrigation promoted earliness of maturity. This was very important in 1899, since cabbage sold before July 10 at prices that netted from $1.65 to $1 per barrel of about 95 pounds. After July 10 they netted from 55 cents to 20 cents per barrel. The amounts received, net, from the different plats were as follows:

Amounts received per plat for cabbage.

Plat 1	$5.10	Plat 5	$4.82
Plat 2	5.45	Plat 6	4.83
Plat 3	3.82	Plat 7	3.10
Plat 4	4.53	Plat 8	3.94

Plats 1, 2, 5, and 6 constitute one-quarter of an acre of irrigated cabbage; plats 3, 4, 7, and 8, one-quarter of an acre of unirrigated. The two differ only as regards irrigation. The net income from the irrigated quarter acre was $20.20, or $80.80 per acre; from the unirrigated, $15.39, or $61.56 per acre. The cost of irrigating 1 acre of cabbage three times was approximately $2.50. The capacity of the plant was sufficient to irrigate 20 to 30 acres of cabbage; thus the profit

from irrigation on 25 acres of early cabbage at this rate would have paid for the plant (see page 32). The yield was small, owing to the character of soil. The gain was 31.3 per cent. A gain due to irrigation of over 30 per cent, when applied to soil of good character, would show much greater profits than in this case.

YELLOW GLOBE DANVERS ONIONS.

This experiment was designed to show the effect both of irrigation and of different quantities of nitrate of soda. The soil was apparently not uniform and the stand was irregular, so that the yield from the unirrigated plat was greater than the actual yields from the irrigated plats. When, however, the latter were calculated to the same stand as on the irrigated plat a decided benefit from irrigation was found. The results as regards nitrate of soda were inconclusive.

MISCELLANEOUS CROPS.

The sowed corn, sweet corn, sweet potatoes, Lima beans, white potatoes, watermelons, cucumbers, and tomatoes were well fertilized and cared for in every case, the irrigated and unirrigated plats being treated exactly alike in every respect, except as regards irrigation. The plats were usually one-eighth of an acre in size, two rows of the crop on each plat being irrigated and two unirrigated, with a wide space between.

The following table gives the dates of planting, of irrigation, and the yields:

Dates of planting and irrigating and yield of crops.

Crop.	Date of planting.	Date of irrigations.	Yield. Irrigated.	Yield. Unirrigated.	Increase due to irrigation.
					Per cent.
Sowed corn	May 6	June 2 June 16 June 3	373 pounds dried stalks.	400 pounds dried stalks.	No gain.
Sweet corn	do	June 2 July 3	440 ears (406 pounds).	325 ears (288 pounds).	5.6 51.5
Sweet potatoes	May 8	June 2 June 16 July 3 Sept. 8	423 pounds, prime.	245 pounds, prime.	72.6
Lima beans	May 8, replanted.	June 2 July 30 Sept. 8	270 pounds, pods.	218 pounds, pods.	23.8
Tomatoes	May 23	June 2 July 3	547 pounds, prime.	573 pounds, prime.	No gain.
Watermelons	May 6, replanted.	June 2 June 16 July 3	74 melons (1,198 pounds).	54 melons (830 pounds).	37.0 44.0
Cucumbers	do	June 16 July 3	176 pounds	210 pounds	No gain.
White potatoes		June 7 June 16	322 pounds, prime.	236 pounds, prime.	36.4
Bush Limas	May 27	June 2 July 3 Sept. 8	74 pounds, pods.	68 pounds, pods.	8.8

A considerable portion of this produce was taken by a trucker, and the estimates of profit are made from receipts from him. In the case

of the sweet potatoes the estimates are made from net receipts from the New York market at time of harvesting.

Tomatoes were worth from 15 to 20 cents per basket during the early season, and 5 cents per basket later. The profit from irrigation amounted to about $18 per acre.

The price of watermelons was higher at the first picking, but it held up fairly well until the last two pickings, when the vines had blighted and injured the quality of a part of the melons. Leaving out of account the last two pickings, the yields of the two plats were: Irrigated, 38 melons, weighing 713 pounds; unirrigated, 27 melons, weighing 495 pounds. A 25-pound melon was worth 15 to 20 cents early, and 10 cents during the greater part of the season. On this basis the profit from irrigation would amount to about $25 per acre.

The effect of irrigation on sweet potatoes was very noticeable. September 4 40 hills were dug from each plat; 62 pounds "prime" and 30 pounds "seconds" were secured from the irrigated plat; 35 pounds "prime" and 30 pounds "seconds" from the unirrigated plat, or a gain of 77.1 per cent of "primes." September 6 the same number of hills were dug into and the large potatoes removed, leaving the hill undisturbed, as far as possible. One hundred pounds were taken from the irrigated and 53 pounds from the unirrigated, a gain of 88.7 per cent. Immediately after this the sweet potatoes were thoroughly irrigated. The object of this test was to ascertain if some potatoes could be withdrawn early and then by thorough irrigation the small potatoes be made to grow into "primes" by the usual digging time. The results would indicate that this could be done. The price at the various digging times was $1.50 per barrel, primes, net, and 80 cents for seconds, and 25 cents for thirds. Before September 4 the price was considerably higher, and some could have been dug earlier, especially from the irrigated plat. The profit accruing from irrigation was $43.68 per ace. The expense of irrigating sweet potatoes would be about the same as for early cabbage.

It will be noticed that irrigation was injurious to sowed corn and cucumbers in these experiments.

CONSTRUCTION AND COST OF SMALL IRRIGATION PLANTS.

The irrigation practiced in the East thus far has been on a small scale. Plants capable of irrigating 6 to 8 acres are the rule. In the following pages several small plants recently installed are described in detail as to construction and cost, in order that those interested may determine from the data given whether under their conditions the installation of plants will prove profitable investments.[1]

[1] For descripton of other irrigation plants in New Jersey, see U. S. Dept. Agr., Office of Experiment Stations Bul. 35.

PLANT OF GEORGE A. MITCHELL, VINELAND, N. J.

The irrigation works of George A. Mitchell consisted originally of a 2.5-horsepower gasoline engine, a single-acting force pump and delivery pipe, consisting of a 2.5-inch wrought-iron pipe, and condemned fire hose, and homemade distributing hose of tarred duck cloth. The engine and pump were inclosed in a building near the bank of a creek, a ditch leading the water to the pump. The water was then pumped 693 feet to the highest point on the farm, whence it was carried to different locations in the same manner as is now done. From 40 to 60 gallons per minute were pumped.

Figure 1 shows the shape, surroundings, location of pumping plant, and topography, etc., of the farm.

The slopes from the 20-foot elevation to the creek and south to Elmer road are comparatively regular, being steepest for about 150 feet each side of the highest point.

In the spring of 1899 the engine and engine house were moved farther away from the creek, and a ditch 15 rods long by 2½ feet wide was dug

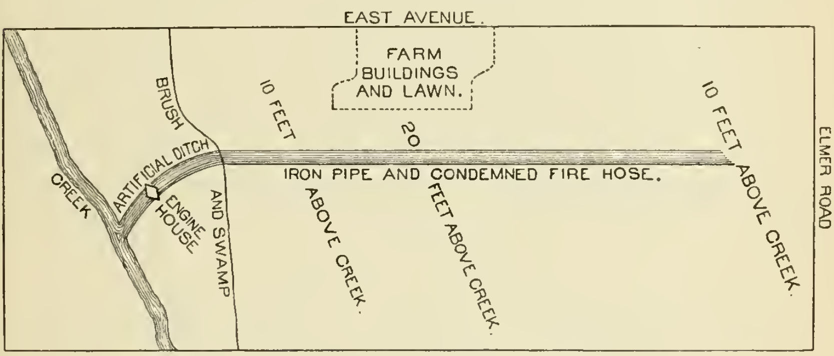

FIG. 1.—Irrigation plant of George A. Mitchell.

to bring the water to the pump. The water in the creek is raised 6 to 12 inches by a dam. A No. 2 centrifugal pump was secured with a 10-inch pulley, and set 10 feet center to center of pulleys from engine. The 3-inch leather belting runs from 2½-foot fly wheel of engine to pulley on pump. The engine makes 320 revolutions per minute.

An 18-foot length of 3-inch pipe is fastened to the pump outlet by means of reducers, and is held in a perpendicular position by four guy wires. An elbow with a 2-foot length of pipe is fastened to the top of the upright or standpipe. The hose is fastened to this by binding with wire. The hose used is of the home-made kind hereafter described, and is 7½ inches in diameter. The different lengths are connected by inserting a short length of stovepipe into the two ends and binding the hose to the pipe with wire. The large hose is used as the main, and extends 425 feet from the standpipe to the highest point on the farm. The hose is supported on a trestlework, which slopes 4 feet

from the standpipe to the end. This slope is sufficient to cause the water to flow through the hose without any forcing from the engine, and consequently there is almost no pressure tending to burst the hose. For 150 feet from the end of the pipe the hose rests on foot-wide wire netting (chicken wire netting) supported on cedar poles. For the rest of the distance the hose is supported in a trough made from cedar slabs. When the hose was 10 to 20 feet above the ground it would have been very difficult to build the trough. Where the hose strikes the ground at the top of the hill it connects with a distributer of galvanized sheet iron (fig. 2). The large opening of this distributer

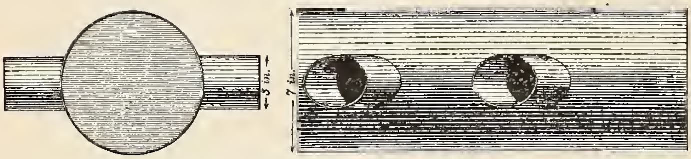

FIG. 2.—Galvanized iron distributer for water hose.

is about 7 inches in diameter and the smaller openings are 3 inches in diameter. Small hose is attached to the small outlets and the water is taken to the land to be irrigated through this. All the water from the pump, about 150 gallons per minute, can be forced through two openings when so desired. Some condemned fire hose that has been used during two years was used as distributing mains. This was laid in such a way as to interfere as little as possible with cultivation, being left in place during the summer and stored in the barn in the fall.

TARRED DUCK HOSE.

This hose was made from 12-ounce duck torn into strips of the desired width and sewed into hose on a sewing machine. A mixture of four parts coal tar to one part boiled linseed oil was then brought to a boil and the hose drawn first through the hot tar and next through a clothes wringer. Care should be taken not to allow the hose to touch the sides of the vessel when it is hot, as it is liable to scorch the hose. Some of the hot mixture should be poured into the hose, before starting it through the wringer, to cover the inside with tar. The hose should dry two or three days, or better a week or more, before being used.

COST OF PLANT.

A statement of the cost of the above described plant follows:

Chief items in cost of George A. Mitchell's plant.

2½ actual horsepower Webster gasoline engine, set up on a brick foundation	$160
Pump set up	40
Belt and adjustments	8

400 feet 2½-inch wrought-iron pipe, tees, laying, and painting	$45
Condemned fire hose, 900 feet, with connections, price not constant (approximately)	36
Building for engine, trench for leading water to pump, various arrangements for distributing water, etc. (approximately)	40
Total	329

PLANT OF W. P. STOKES, MOORESTOWN, N. J.

Mr. Stokes erected an irrigation plant early in 1899. He uses a 2½-horsepower gasoline engine, a single-acting force pump (cylinder 6 by 12 inches). His source of supply is three driven wells, with 2-inch pipe. These three driven wells are connected and the pump draws from all three at once; a flow of 50 to 60 gallons per minute being secured, although the wells would yield a great deal more. Before putting down the drive wells, an open well 15 feet deep and 8 feet in diameter was dug and bricked. Considerable trouble was

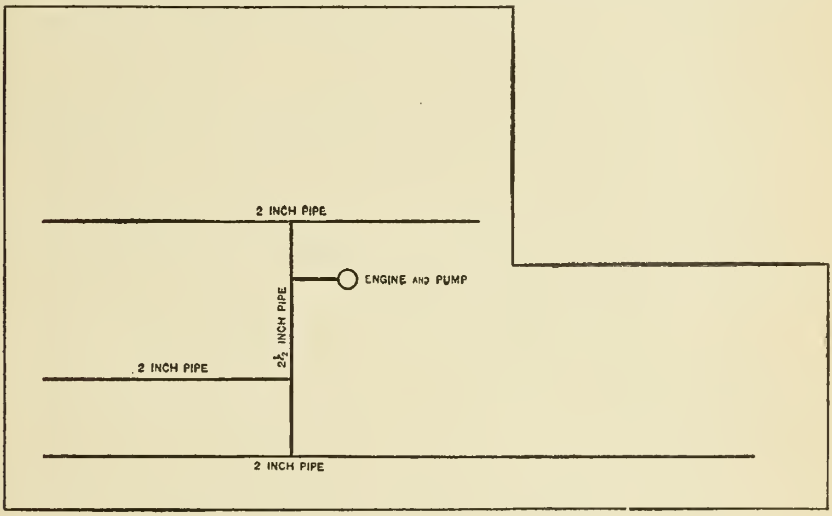

FIG. 3.—Plan of irrigation plant of W. P. Stokes.

experienced on account of the well caving in while being dug. The chief object of digging the well was to remove a bed of clay that might make the driving very difficult. The three wells were driven from the bottom of the open well as far distant from each other as the diameter of the well would permit. The working heads and cylinder of the pump were put as near the bottom of the well as possible. The combination countershaft for the belting from the engine and for working the pump was at the top of the open well. The engine is placed at the usual distance from countershaft, i. e., 10 feet from center to center of pulleys. The engine is set on a brick foundation. The water is forced through distributing mains. The system of pipes is shown in fig. 3.

The wrought-iron pipe leading from the pump, 75 feet in length, is $2\frac{1}{2}$ inches in diameter. Four other pipes, 2 inches in diameter, lead out from the $2\frac{1}{2}$-inch main. Fifty-foot lengths of tarred-duck hose are used for distributing the water. The outlets for attaching the hose are 25 feet apart. This hose is attached to a distributer 9 feet in length and 3 inches in diameter. There are six outlets $1\frac{1}{4}$ inches in diameter. The rows of plants, flowers, and truck are planted 18 inches apart where possible, so that the six outlets of the distributer allow the water to flow between the six rows.

Mr. Stokes's land has gentle slopes, so that the water will easily run between the rows. There are 4 acres, including the lawn. A ridge runs through the middle, giving a natural slope in two directions, except that at one corner there is a rise.

As at present equipped, 60 gallons per minute can be pumped. There is reason to believe that the wells will yield much more water, but 60 gallons per minute is the capacity of the pumps. This is sufficient to cover 7 acres 1 inch deep each week, when the pump is kept going $10\frac{1}{2}$ hours six days in the week.

Mr. Stokes has a clay subsoil. He grows a small amount of garden crops, devoting the larger part of his place to growing flower seeds, plants, and bulbs.

COST OF PLANT.

The chief items of expense in preparing for irrigation are as follows:

Chief items in cost of W. P. Stokes's plant.

Engine and pump erected	$190
Driven wells	60
Labor (estimated)	20
Total	270

The expense of operation is about 40 cents for ten hours, besides one man's time.

PLANT OF SCRIBNER BROTHERS, NAVESINK, N. J.

Scribner Brothers installed an irrigation plant in the spring of 1899. They use an engine, pump, and hose like those used by George A. Mitchell (p. 31). The water is pumped from a small artificial pond, which is fed by a brook. Water is lifted and forced through a 3-inch pipe to a height of 18 feet at the rate of about 200 gallons per minute. The hose is laid in troughs made of inch boards, which are supported by single poles with side supports.

The main hose, 6 inches in diameter, slopes a little less than 1 foot in 100 from the delivery pipe to the highest point on their 10-acre truck farm. Three side lines of 4-inch hose can be extended across

the farm. The main is permanent, but the side lines are laid down when irrigation is wanted. The T's used in the main hose for connecting with the side lines are made from stovepipe riveted together and dipped in coal tar and oil. They use, altogether, 2,800 feet of hose. They use two distributers similar to the one used by Mr. Mitchell.

COST OF PLANT.

The total cost of this plant, not including labor performed by Scribner Brothers, was approximately $400. The chief items of expense were as follows:

Chief items in cost of Scribner Brothers' plant.

Engine and pump erected, with suction and discharge pipe	$200.00
Pond	5.50
Building 6 by 14 feet	7.00
Hose and connections	92.50
Troughs	45.00
Labor (estimated)	40.00
Total	390.00

If the pump is kept going ten hours per day, six days in the week, 1 inch of water could be put on 25 acres each week. It would not be advisable to calculate on watering that acreage, however, as it is best to have a larger plant, so as to allow for some hindrances. The Scribner Brothers' soil is gravelly to sandy loam. It costs them, to distribute the water, 75 cents per day, besides the time of four men on small plants and two men on large vegetables or trees.

Scribner Brothers have irrigated about six acres of crops, as follows: Tomatoes, cabbage, cauliflower, beets, carrots, radishes, potatoes, corn, strawberries, blackberries, raspberries, asparagus, celery, onions, lettuce, parsnips, salsify, rhubarb, parsley, and some other crops. They do not use less than 2 inches of water at each irrigation, and from that up to 4 inches. Four inches was put on berries of the bush variety. They report that irrigation this year has paid on all crops to nearly the extent of the cost of the plant.

PLANT OF HON. J. J. GARDNER, EGG HARBOR, N. J.

This plant was erected during the summer of 1899. It consists of an engine and pump like those used by George A. Mitchell and Scribner Brothers. The water is secured from a large open well, 12 by 12 feet. This well was dug by making a large curb of inch boards that would settle as fast as the bottom was dug out. After getting down 10 feet there was a great deal of fine clay. This was taken out by stirring the bottom and pumping out the muddy water with the centrifugal pump. The engine and pump are capable of drawing from 170 to 200 gallons of water per minute, but the capacity of the well at a depth of 12 feet is about 500 gallons per hour.

This farm of 300 acres is nearly all divided into slight slopes just right for allowing the water to flow slowly between rows of plants. It is intended to make ditches along the ridges to carry the water, which will be allowed to flow over the side of the ditch at intervals desired. No irrigation was practiced this year, as the machinery was not in position in time. A number of pumping plants (at least five), with a water supply of 150 to 200 gallons per minute, would be needed to irrigate the 100 acres that it is intended to water.

Strawberries, blackberries, early potatoes, onions, corn, grass, etc., are grown.

COST OF PLANT.

The chief items of expense in preparing for irrigation are as follows:

Engine and pump	$210
Hose	20
Total	230

PLANT OF WILLIAM ASH & SONS, VINELAND, N. J.

William Ash & Sons have a very fertile half-acre plat fitted with overhead pipes, to which water-witch sprinklers are attached for irri-

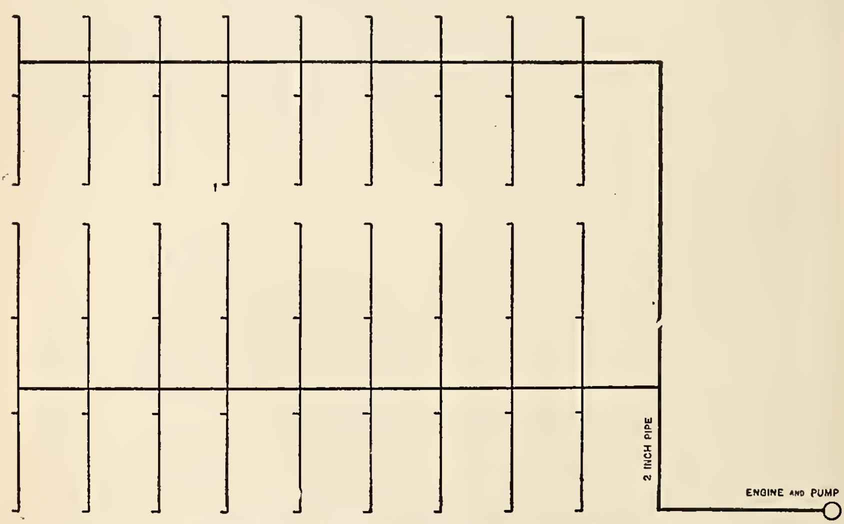

FIG. 4.—Irrigation system of William Ash & Sons.

gation by sprinkling. They use a $2\frac{1}{2}$-horsepower gasoline engine and a Bulldozer power pump, which also supplies water for one-half acre under glass. The water—30 gallons per minute—is forced through a 2-inch main, then through two $1\frac{1}{2}$-inch laterals into several three-fourths-inch laterals, to which are attached 61 water witches 24 feet apart each way. (Fig. 4.) This system of pipes is supported on poles high enough to allow a horse to pass underneath.

They intend to put the pipes under ground, and to have perpendicular pipes to which the water witches are to be attached. Instead of forming squares the water witches will be arranged diamond shape. Seven water witches are operated at one time, the water being shut off from others by faucets.

The half acre can be thoroughly watered in five hours. The water is pumped from an open well, in which the water stands within 8 to 10 feet from the surface of the ground.

COST OF PLANT.

The chief items of expense in preparing for irrigation are as follows:

Pipe and water witches	$250
Engine and pump	200
Total	450

This year cauliflower, followed by lettuce, was grown on this irrigated half acre. There is very little labor involved in the distribution of the water by this method. A man turns on and shuts off the water for the different side pipes. Only a small fraction of the power of the engine is used, so that much more water could be distributed through this system than is done if a larger pump were used. The soil is sandy and is heavily manured each year with New York horse manure.

PLANT OF CUNO BECKER, VINELAND, N. J.

Cuno Becker's windmill irrigation plant has been described in a former bulletin of this Office.[1] In 1899 he used a 2½-horsepower gaso-

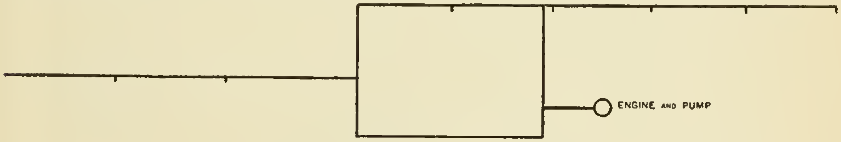

FIG. 5.—Irrigation system of Cuno Becker.

line engine to operate his pump when the windmill did not pump enough water to keep his acre of ground thoroughly irrigated. His tank holds 4,000 gallons, which he fills with his engine and pump in about five hours. Only a fraction of the total power of the engine is used. Overhead three-fourths-inch pipe is supplied with faucets every 40 feet, to which are attached rubber hose leading to water witches that can be moved from place to place. (Fig. 5.) Two water witches kept at work continually during dry weather keep 1 acre of very rich sandy land thoroughly irrigated when planted very close in beets, radishes, lettuce, strawberries, or cabbage.

[1] U. S. Dept. Agr., Office of Experiment Stations Bul. 36.

COST OF PLANT.

The chief items of expense in preparing for irrigation are as follows:

Engine	$150
Piping	13
Hose, faucets, and water witches	20
Labor (estimated)	7
Total	190

A 2-inch pipe is used for a main leading from the pump. One man working about the garden can attend to the engine and move the sprinklers occasionally.

COST OF SMALL IRRIGATION PLANTS IN NEW JERSEY.

The following table brings together the data so far secured relating to the cost of small irrigation plants in New Jersey:

Cost of small irrigation plants.

Name.	Place.	Method.	Power.	Acres irrigated.	Crop.	Cost.
John Repp	Glassboro, N. J	Pumping.	Steam	5	Strawberries, lettuce, and onions.	$600
Josiah H. Shute	Pitman Grove, N. J	do	Windmill	1	Onions, celery, and Lima beans.	156
A. P. Arnold	Vineland, N. J	do	do	10	Sweet potatoes and garden produce.	250
T. H. Whitney	Glassboro, N. J	do	Water power	10		
Thos. R. Hunt	Lambertville, N. J.	do	Gasoline engine	10	Berries, onions, celery, and asparagus.	360
Geo. A. Mitchell	Vineland, N. J	do	do	10	Garden crops	329
S. O. Garrison	do	do	Steam	10	Corn and celery	500
W. P. Stokes	Moorestown, N. J	do	Gasoline engine	7	Flowering plants, market garden.	270
Scribner Bros	Navesink, N. J	do	do	10	Garden produce	390
J. J. Gardner	Egg Harbor, N. J	do	do	10	Strawberries, blackberries, potatoes, onions, corn, grass.	230
Wm. Ash & Sons	Vineland, N. J	do	do	[1] 1	Garden crops	450
Cuno Becker	do	do	Gasoline engine and windmill.	1	Beets, radishes, lettuce, cabbage, and strawberries.	190

[1] Plant is much larger than is required for one acre.

No general statement can be made as to the value of the increased yields due to irrigation, but the owners of the above plants are all satisfied that their installation has been very profitable, and in nearly every instance have stated that they have made the cost of the plant in the increased crops the first year.

METHODS OF DISTRIBUTING WATER.

FURROW IRRIGATION.

Irrigation by furrows consists simply in allowing water to flow between rows when the plants are large enough to fill the ground with roots, or in making a furrow in which to run the water next the row on one or both sides of small plants. Furrow irrigation has been most successful on potatoes where there was just enough slope to make the water flow slowly when a large volume is started down the row. With greater slopes irrigation washes the soil in proportion to the steepness of the slope. Where the ground has too little slope to make the water flow well, several lengths of tarred hose may be laid down the row, and when the water has flowed nearly the length of the first piece a connection is made and the water let out at the end of the first length, and so on. This plan should be followed when the row is so long that the upper end gets too wet before the lower end gets wet enough. Where the land slopes so much that a large volume of water washes the land, the difficulty can be partially overcome by dividing the water into small streams and running it down several rows at once. This is done by making small ditches or furrows with the hoe to carry the stream to the different rows, or it may be done with a distributer.

A small hose is attached to the openings and carries the water to the row desired. With these pieces of small hose, about 25 feet long, there is no need to change the position of the distributer until a space 50 feet feet wide has been watered. The distributer is made of tin or sheet iron.

When there is a long gentle slope, the lower end of the land is very often more moist than the upper end, although rows of potatoes 500 feet long have been successfully irrigated by starting the water at the upper end of the row and allowing it to flow the entire distance.

In connection with furrow irrigation, the question naturally arises, How far does the water soak laterally? When potatoes are ridged and the water run between the rows, there will be lateral soakage enough in sandy soil to make the soil under the potato row quite moist.

FLOODING SMALL BEDS OF PLANTS.

Small beds of plants often need careful and thorough watering. It is quite commonly supposed that sprinkling is the only available method in this case. Two methods of flooding were tried on beds of cabbage plants. In one case, the bed was plowed so as to slope toward the dead furrow in the middle. Small furrows were then made along the two edges of the bed with a hand plow. Water was run down the two small furrows, and made to overflow by damming with a board at short intervals. Water was also run down the center furrow and allowed to overflow, but this was not very effective.

In another case the bed was plowed so as to leave the whole a slight ridge. A furrow was made with the hand plow down the center of this ridge, and water ran down and allowed to overflow on one side only. Both of these methods were found to be very satisfactory. When the plants were of considerable size, the ground was thoroughly wet without wetting the leaves. It worked better after the first irrigation, or after the freshly plowed ground had been rained on. One irrigation was performed on the freshly made bed, and although it was successful, considerable trouble was caused by the washing away of the bank of the small ditch.

For irrigation by use of water witches, see description of Cuno Becker's and William Ash & Sons' irrigation plants (pp. 36, 37). This method is expensive, both as to power required and original cost of plant, but it is claimed to have proven very satisfactory in the cases mentioned in which the planting was so close that it would have been difficult to irrigate in furrow.

John Repp, of Glassboro, N. J., irrigates 3 acres of field lettuce when small by means of movable sprinklers attached to rubber hose. When the lettuce is large he floods the ground by letting the water flow out of the open ends of hose, moving the hose from place to place. He considers the method very satisfactory.

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